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INSTRUCTION MANUAL

MODEL 2173C

TRANSISTOR NOISE ANALYZER
CONTROL UNIT

FOR SERIAL NO. _____

Quan-Tech LABORATORIES, INC.

INSTRUMENTS • AMPLIFIERS • NOISE INSTRUMENTATION

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FOR SERIAL NO. _____

Quan-Tech LABORATORIES

43 SOUTH JEFFERSON ROAD

WHIPPANY, NEW JERSEY 07981

201-887-5508

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CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Quan-Tech Laboratories, Inc. warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Electronic tubes and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misadjustments, misuse, or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

Calibration checks of this instrument can easily be made in accordance with the instruction manual. Routine readjustments should never be attempted. If, however, the instrument has been damaged and requires recalibration or alignment, explicit calibration procedures as defined in the instruction manual must be followed.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.
2. On receipt of shipping instructions, forward the instrument prepaid, to the factory. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

The instruments should be packed in their original containers, or in a strong exterior container and surrounded by two inches of shock absorbing material.

Quan-Tech L A B O R A T O R I E S

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SECTION 1

GENERAL

A. DESCRIPTION

The Quan-Tech Model 2173-C Transistor Noise Analyzer Control Unit provides the means for applying the dc bias, and the noise monitoring circuitry required for measuring the various noise parameters of transistors within the range of the equipment.

The Control Unit is automatically calibrated to provide a constant gain characteristic which is in-

dependent of the parameters of the transistor under test or the quiescent operating condition.

When used with an appropriate filter unit, such as the Model 2181, noise measurements may be made over the frequency range of from 10Hz to 100KHz. Measurements are typically made of the equivalent noise voltage (E_N), equivalent noise current (I_N), and/or Noise Figure for any desired input resistance.

B. SPECIFICATIONS

Collector Voltage:	0.3 to 60 volts. Metered in four ranges: 3, 10, 30, and 100V, full scale.
Collector Current:	0.3 microamperes to 30 milliamperes. Metered in ten ranges: 1, 3, 10, 30, 100, microamperes, .3, 1, 3, 10, and 30 ma. full scale.
Gate Voltage:	Zero to ± 15 VDC. Polarity selected with meter range switch. Meter ranges 3, 10, 30 volts full scale.
Base Resistance:	Short circuit to one megohm. The following resistors selected with a front panel switch: 0, 500 ohms, 1K, 10K, 100K ohms, and 1 megohm. Mounting terminals and

Output Parameters:

a switch position are provided to permit the use of a particular value of external base resistance.

Voltage gain: AGC circuitry maintains constant gain of ten thousand. Bandpass: 5Hz to 100KHz. Output Impedance: 1K ohm. Max. Output Voltage: 5.5 VRMS. 117/234 volts, 60Hz. 5¼" x 19" standard rack panel, 16" deep overall. 30 pounds.

Power Input:

Dimensions:

Weight:

C. ACCESSORIES:

One Type 1113 Cable is supplied. This cable is used to connect the Model 2173C to the Filter Unit.

SECTION 2

OPERATION

A. FIRST TIME OPERATION

The procedure given below will enable an operator to energize the equipment and through the use of an appropriate Filter Unit make basic transistor noise measurements. It is highly recommended, however, that the remainder of SECTION 2 be read to obtain a greater understanding of the function of the equipment.

1. Plug the line cord of the Filter Unit into the line receptacle provided at the rear of the Control Unit.
2. Connect the noise output of the Control Unit to the noise input of the Filter Unit using the Type 1113 cable provided.
3. Plug the line cord of the Control Unit into a suitable supply of 117V, 60Hz line power and turn the power switch to ON.
4. Set the Control Unit front panel controls as follows:
 - a) NPN/PNP selector for proper type.
 - b) COLLECTOR/DRAIN VOLTAGE switch and ADJ. control for desired transistor collector voltage.
 - c) COLLECTOR/DRAIN CURRENT switch to desired current range and ADJ. mid range.
 - d) BASE RESISTANCE switch to E_N position.
 - e) BIAS SELECTOR switch to the COLLECTOR/DRAIN CURRENT position.
5. Set Filter Unit attenuators and multipliers to fully clockwise positions.
6. Insert the transistor to be tested and close the shield cover.

WARNING! Never insert a transistor in the test socket when the interlock button is depressed, as damage to the transistor may result.

NOTE: The instrument should now be operating and the CURRENT meter should come up to read approximately mid scale. A relay "click" may be heard after the CURRENT meter has come up to a stable reading. The fact that this relay has energized indicates that the Control Unit is functioning in the normal way.

7. Set the COLLECTOR/DRAIN CURRENT ADJ. control for the desired collector current.

NOTE: If conditions for a proper noise measurement are not met in the Control Unit there will be no input to the Filter Unit

and all noise meters will read zero. (The relay mentioned above does this switching at the output of the Control Unit). The relay can be expected to temporarily operate if either the CURRENT or VOLTAGE is changed at a rate sufficient to block the noise amplifier channel.

8. Set the NOISE VOLTAGE F.S. switch and the SCALE MULTIPLIERS on the Filter Unit for on scale meter indications at all measuring frequencies.

The NOISE meters are now indicating the equivalent noise voltage parameter (E_N) of the transistor under test.

Noise figure measurements are made by inserting the desired base resistance in the test circuit, reading the total noise voltage on the NOISE meters and converting to noise figure either through the use of the conversion chart given in Figure 2-1 or by computation:

The equivalent noise current parameter (I_N) of the transistor under test is measured by inserting a high value base resistance in the test circuit, reading the total noise voltage on the NOISE meters and applying the following equation:

$$I_N = \frac{\left(E_{\text{Total}}^2 - E_N^2 - E_{\text{Thermal}}^2 \right)^{1/2}}{R_g}$$

where:

I_N = equivalent RMS noise current generator referred to the base of the transistor under test for a one Hz bandwidth.

R_g = Magnitude of the series base resistance in ohms.

E_{Total} = Noise voltage read on panel meters with R_g in the test circuit.

SECTION 2

OPERATION

E_N = equivalent RMS noise voltage generator measured in the E_N ($R_g = 0$) position of the BASE RESISTANCE switch. E_N is also referred to the base of the transistor under test for a one Hz bandwidth.

E_{Thermal} = RMS thermal noise voltage of R_g for a one Hz bandwidth.

B. FRONT PANEL METERS AND CONTROLS

1. Test Jig Cover

The very low measuring levels of this equipment require that the test sockets, test transistor and base resistors be shielded when a noise measurement is being made. The hinged cover accomplishes the required shielding and also activates an interlock switch which removes the voltages from the test socket for loading and unloading. This cover should therefore be closed when a noise measurement is being made.

WARNING!

Never insert a transistor in the test socket when the interlock button is depressed, as damage to the transistor may result.

2. BASE RESISTANCE

The external base resistance for the transistor under test may be selected with this switch over the range from a short circuit to one megohm. A switch position and solder terminals are provided for using a resistance value not provided.

3. NPN, N CHANNEL - PNP, P CHANNEL

The polarity of the d-c COLLECTOR/DRAIN VOLTAGE is selected with this switch. Either positive or negative base/gate voltage is available for both positions of the switch.

4. BIAS SELECTOR

The transistor under test may be biased by programming either the collector/drain current or the base/gate voltage. Meters and controls are provided for each of these modes of bias.

5. GATE BIAS VOLTAGE Meter, Range Switch and ADJ.

When the BIAS SELECTOR switch is in the GATE BIAS VOLTAGE position, the polarity of the gate to source bias voltage is selected with the GATE BIAS VOLTAGE meter range switch. The magnitude of the bias voltage is selected with the ADJ control. Note that the BIAS VOLTAGE meter reads correctly only when the test fixture shield cover is closed, and does not read at all in the COLLECTOR/DRAIN CURRENT position of the BIAS SELECTOR switch.

6. COLLECTOR/DRAIN CURRENT Meter, Range Switch and ADJ.

a. In the GATE BIAS VOLTAGE position of the BIAS SELECTOR switch, the CURRENT meter and range switch function strictly as a multi-range ammeter. Under these conditions the ADJ control does not function.

b. In the COLLECTOR/DRAIN CURRENT position of the BIAS SELECTOR switch the range switch and the ADJ control actually determine the current in the device under test. Automatic bias circuitry provides any bias voltage between 10V to achieve the selected collector or drain current. The range of the ADJ control is from slightly less than one third of full scale to slightly greater than full scale on all current ranges.

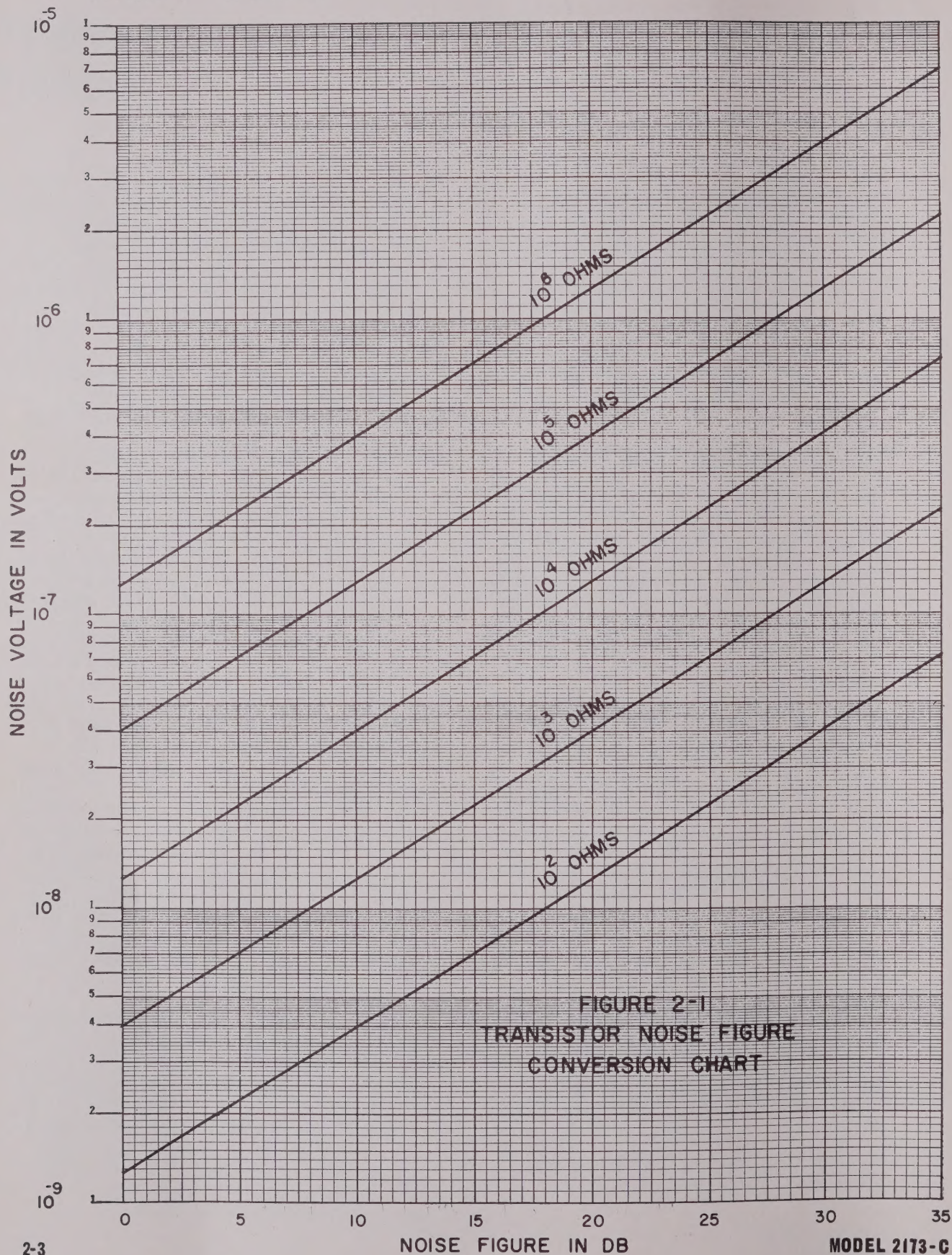
7. COLLECTOR/DRAIN VOLTAGE Meter, Meter Multiplier and ADJ.

The COLLECTOR/DRAIN VOLTAGE switch is a multiplier switch for the voltmeter and does not change the collector to emitter voltage. The voltage read on the voltmeter is the magnitude of the collector to emitter voltage of the transistor under test. This voltage may be preset before the transistor is inserted in the test socket as the voltmeter reads the applied voltage correctly with or without a transistor in the jig.

8. Power Switch

The power switch on the Control Unit applies power to a line receptacle at the rear of the unit in addition to the unit itself. This feature is included to provide a switched power source for the accompanying Filter Unit which requires AC power but does not have its own power switch,

SECTION 2 OPERATION



June 15, 1966

A DISCUSSION OF ERRORS DUE TO BANDWIDTH WHEN MAKING SPOT NOISE MEASUREMENTS

Considerable confusion occasionally arises over the effect that bandwidth has on the accuracy of spot noise measurements which, by definition, refer to an equivalent noise bandwidth of one Hz. Practically all noise analyzers use an equivalent noise bandwidth much greater than one Hz and effectively divide the actual noise voltage by the square root of the bandwidth to obtain spot noise or noise spectral density. If the noise being measured is white (amplitude constant with frequency) there is no problem in accepting the above philosophy, however, most semiconductors generate considerable amounts of $1/f$ noise which has an amplitude characteristic inversely proportional to the square root of the frequency. The question arises as to how much error is introduced in a given bandwidth if $1/f$ noise is present. Some transistor specifications have even gone so far as to specify the bandwidth (200 Hz for 1 KHz spot noise figure) in an attempt to minimize the error. The following analysis has been made to show that bandwidth, within reason, contributes basically no error regardless of whether white or $1/f$ noise is present.

Spot noise measurements (equivalent noise bandwidth of one Hz.) taken on a Quan-Tech Laboratories Model 310 are actually made with filter bandwidths of typically 300 Hz and 900 Hz for the 1 KHz and 10 KHz channels respectively. The error in the noise measurement introduced by measuring over these particular bandwidths instead of one Hz bandwidth is as follows:

Conversion factors for white noise:

$$E_{\text{total in 300 Hz BW}} = E_{1\text{KHz}} (300)^{1/2} = E_{1\text{KHz}} (17.32)$$

$$E_{\text{total in 900 Hz BW}} = E_{10\text{KHz}} (900)^{1/2} = E_{10\text{KHz}} (30)$$

Conversion factors for $1/f$ noise

$$\begin{aligned} E_{\text{total in 300 Hz BW}} &= E_{1\text{KHz}} (1\text{KHz})^{1/2} \left(\ln \frac{f_2}{f_1} \right)^{1/2} \\ &= E_{1\text{KHz}} (31.6) \left(2.3 \log \frac{1160}{860} \right)^{1/2} \\ &= E_{1\text{KHz}} (17.30) \end{aligned}$$

$$\begin{aligned} E_{\text{total in 900 Hz BW}} &= E_{10\text{KHz}} (10\text{KHz})^{1/2} \left(\ln \frac{f_2}{f_1} \right)^{1/2} \\ &= E_{10\text{KHz}} (10^2) \left(2.3 \log \frac{10460}{9560} \right)^{1/2} \\ &= E_{10\text{KHz}} (29.9) \end{aligned}$$

It can be seen from the above that the error resulting from using the white noise conversion factor when the noise is actually $1/f$ is essentially zero. Even bandwidths as wide as 1 KHz geometrically centered around 1 KHz contribute negligible error compared to the other errors usually associated with the measurement of random noise.

1 KHz SPOT NOISE FIGURE VS BROADBAND NOISE FIGURE ⁽¹⁾

The following is an analysis of the difference to be expected between noise figure measurements made by these two presently accepted standards.

The 1 KHz spot noise figure is measured at 1 KHz with the bandwidth of the detector small as compared to 1 KHz. Both the thermal noise of the source and the white, as well as 1/f noise contributed by the device under test are measured at 1 KHz only.

In the broadband case, the noise figure is measured over a bandwidth extending from 10 Hz to 10,000 Hz. This bandpass is specified to be 3db down at 10 and 10,000 Hz, and to have a 6db/oct roll-off. The broadband noise figure is a measure of the white and 1/f noise generated within this bandpass, including the skirts.

Table No. 1 lists the noise figure for both the broadband and 1 KHz spot methods, assuming all white noise to be generated by the source resistance, and all noise generated by the device, to be 1/f. This results in the maximum deviation between the two methods. If the device under test contributes white noise (thermal and shot) as well as 1/f noise, the difference will be less.

TABLE NO. 1

1 KHz spot noise figure in db	Broadband noise figure in db	Δ N.F. in db
0.5	0.20	0.30
1.0	0.42	0.58
2.0	1.00	1.00
3.0	1.58	1.42
5.0	2.90	2.10
7.0	4.40	2.60
10.0	6.95	3.05
20.0	16.42	3.58

The noise voltage contained within a bandpass may be expressed as:

$$\overline{E^2}^{1/2} = \left[\int_0^\infty E^2(F) G^2(F) df \right]^{1/2} \quad \text{EQUATION 1}$$

or the voltage squared:

$$\overline{E^2} = \int_0^\infty E^2(F) G^2(F) df \quad \text{EQUATION 2}$$

where $E^2(F)$ describes the noisepower spectrum and $G^2(F)$ describes the power gain of the circuit.

Since the broadband measurement contains a low pass and a high pass filter, the gain function is:

$$G_{LP}(F) = \frac{1}{\left(1 + \frac{f^2}{f_2^2} \right)^{1/2}} \quad \text{EQUATION 3}$$

$$G_{LP}^2(F) = \frac{f_2^2}{f_2^2 + f^2} \quad \text{EQUATION 4}$$

$$G_{HP}(F) = \frac{1}{\left(1 + \frac{f_1^2}{f^2}\right)^{1/2}} \quad \text{EQUATION 5}$$

$$G_{HP}^2(F) = \frac{f^2}{f_1^2 + f^2} \quad \text{EQUATION 6}$$

where f_2 and f_1 are the upper and lower cutoff frequencies.

Thus the magnitude of the white noise contained in the broadband measurement where $E^2(f)$ is a constant for all frequencies and is assigned unit magnitude is given by:

$$\overline{E_W^2} = \int_0^\infty G_{LP}^2(F) G_{HP}^2(F) df \quad \text{EQUATION 7}$$

$$\overline{E_W^2} = \int_0^\infty \left(\frac{f^2}{f_1^2 + f^2} \right) \left(\frac{f_2^2}{f_2^2 + f^2} \right) df \quad \text{EQUATION 8}$$

By partial fraction expansion we have:

$$\overline{E_W^2} = \int_0^\infty \left[\frac{\frac{1}{(f_2^2 - f_1^2)}}{\frac{f_1^2 + f^2}{f_1^2 + f^2}} + \frac{\frac{1}{(f_1^2 - f_2^2)}}{\frac{f_2^2 + f^2}{f_2^2 + f^2}} \right] f_2^2 f^2 df \quad \text{EQUATION 9}$$

$$\overline{E_W^2} = \frac{f_2^2}{f_2^2 - f_1^2} \left(f - f_1 \tan^{-1} \frac{f}{f_1} \right) + \frac{f_2^2}{f_1^2 - f_2^2} \left(f - f_2 \tan^{-1} \frac{f}{f_2} \right) \Bigg|_0^\infty$$

EQUATION 10

$$\overline{E_W^2} = \frac{f_2^2}{f_2^2 - f_1^2} (f_2 - f_1) \frac{\pi}{2} = \frac{f_2^2}{f_2 + f_1} \frac{\pi}{2} \quad \text{EQUATION 11}$$

$f_1 = 10 \text{ Hz}$ and $f_2 = 10,000 \text{ Hz}$

Therefore:

$$\overline{E_W^2} = 15.7 \times 10^3 \text{ VOLTS}^2 \quad \text{EQUATION 12}$$

The derivation of the magnitude of $1/f$ noise is similar to the above for white noise. Prior to integration, equation 9 should be multiplied by $1/f$, since in this case the function $E^2(F) = 1/f$.

$$\overline{E_{1/f}^2} = \int_0^\infty \left[\frac{\frac{1}{(f_2^2 - f_1^2)}}{\frac{f_1^2 + f^2}{f_1^2 + f^2}} + \frac{\frac{1}{(f_1^2 - f_2^2)}}{\frac{f_2^2 + f^2}{f_2^2 + f^2}} \right] f_2^2 f df \quad \text{EQUATION 13}$$

$$\overline{E_{1/f}^2} = \frac{1}{2} \frac{f_2^2}{f_2^2 - f_1^2} (\ln f^2 + f_1^2 - \ln f^2 + f_2^2) \Big|_0^\infty \quad \text{EQUATION 14}$$

$$\overline{E_{1/f}^2} = \frac{1}{2} \frac{f_2^2}{f_2^2 - f_1^2} \ln \frac{f^2 + f_1^2}{f^2 + f_2^2} \Big|_0^\infty \quad \text{EQUATION 15}$$

$$\overline{E_{1/f}^2} = \frac{f_2^2}{f_2^2 - f_1^2} \ln \frac{f_2}{f_1} \quad \text{EQUATION 16}$$

Again $f = 10$ Hz and $f_2 = 10,000$ Hz and

$$\overline{E_{1/f}^2} = 6.9 \text{ VOLTS}^2 \text{ (unit spectral density at 1 Hz)} \quad \text{EQUATION 17}$$

The above solution is based on unit spectral density for the $1/f$ noise at 1 Hz. For comparison the $1/f$ noise should be set equal to the white noise at 1 KHz. Thus a multiplier of 1000 is required and:

$$\overline{E_{1/f}^2} = 6.9 \times 10^3 \text{ VOLTS}^2 \text{ (unit spectral density at 1 KHz)} \quad \text{EQUATION 18}$$

$$\frac{\overline{E_{1/f}^2}}{\overline{E_w^2}} = \frac{6.9 \times 10^3}{15.7 \times 10^3} = .44 \text{ or } -3.58 \text{ db} \quad \text{EQUATION 19}$$

Table No. 1 is derived from equations 20 and 21.

$$\text{1 KHz SPOT N.F.} = \frac{4kTR_g + \overline{E_{1/f}^2}}{4kTR_g} \quad \text{EQUATION 20}$$

$$\text{BROADBAND N.F.} = \frac{4kTR_g(15.7 \times 10^3) + \overline{E_{1/f}^2}(6.9 \times 10^3)}{4kTR_g(15.7 \times 10^3)} \quad \text{EQUATION 21}$$

where R_g - generator or source resistance and $\overline{E_{1/f}^2} = 1/f$ noise spectral density at 1 KHz.

SECTION 3

THEORY OF OPERATION

A. GENERAL

The theory of operation of the Transistor Noise Analyzer Control Unit Model 2173-C can best be understood by referring to the Block Diagram shown in T-5420. The noise signal as well as the collector current of the transistor under test is applied to the preamplifier which is essentially a voltage amplifier and impedance converter designed for minimum noise at the input. From the preamplifier the DC current and voltage of the transistor under test is measured. The DC output of the preamplifier is fed into a voltage controlled oscillator whose AC output is directed proportional to the DC current in the collector of the transistor under test. The AC is then transformer coupled, rectified and applied as a feedback signal to the base of the transistor under test to maintain a constant collector current as required

by the current controls. The noise or AC signal from the transistor under test is fed from the preamplifier to Amplifier #1 and the remainder of the amplifying channel.

A 4 KHz calibrating oscillator is connected to the emitter of the transistor under test. The calibrating oscillator supplies the signal which is used to maintain a constant gain through the amplifier channel so that the noise or the signal at the output can be referred to the input using a constant amplification factor. The 4 KHz signal is sampled at the output point, amplified and compared against a Zener diode reference. The difference signal is then used to drive the compressor which completes the loop to maintain a constant overall voltage gain.

SECTION 4

CIRCUIT DESCRIPTION

A. GENERAL

The Block Diagram, T-5420, shows the basic connections between individual circuits in the Control Unit. In general, the assemblies shown as blocks on T-5420 are separate plug-in printed circuit boards.

Reference to the Block Diagram and appropriate Schematic Diagrams will enable the reader to follow the individual circuit descriptions.

B. POWER INPUT AND COLLECTOR VOLTAGE SUPPLY (Schematic T-5421)

The line connections, power switch and fuses are shown on this schematic. The multiple secondaries are labelled in accordance with their circuit association. The collector voltage supply is a straightforward regulated power supply. The control of the voltage is obtained by adjusting R117 which has a constant current supply to it through R107 from the reference diode CR105. A difference or change in the output voltage is monitored by Q102 and amplified through Q103 and the emitter followers Q105 and Q106. If excessive currents are encountered, Q104 will detect the voltage drop across R114 and cut off the supply. The collector supply for Q106 is a simple rectifier and RC filter.

C. +18 VOLT SUPPLY (Floating Ground) (Schematic T-5422)

The +18 Volt Supply to operate the preamplifier and associated circuitry floats above ground, referenced to the collector voltage supply. In this supply the difference between the reference diode CR204 and the voltage point obtained from the divider R203 and R204 is amplified by the double differential amplifier consisting of Q201, Q202, Q203, and Q204. The signal is then applied to Q205 which controls the output of the supply. Pre-regulation of the collector of Q203 is obtained from CR203.

D. -18 VOLT SUPPLY (Floating Ground) (Schematic T-5423)

The -18 Volt Supply is identical to the supply shown in T-5422 with the exception that the positive terminal is connected to the collector voltage supply.

E. +18 VOLT SUPPLY (Schematic T-5424) -18 VOLT SUPPLY (Schematic T-5425)

These supplies are identical to T-5422 with the exception that they have one output terminal refer-

enced to ground and are used for the main amplifier channel power supplies.

F. VOLT METER CIRCUIT (Schematic T-5426)

The input attenuator to the voltmeter supplies 3V for a full scale reading to the voltmeter circuitry. In the PNP position Q601 and Q602 operate as an inverter having unity gain. In the NPN position the inverter is by-passed and the voltage from the attenuator is applied to the differential pair Q603 and Q604. Q605 is the second stage of amplification and negative feedback is provided by the gain determining resistors R613 and R614. The output of this amplifier drives the voltage analog and the voltmeter.

G. CONTROL OSCILLATOR AND 150 KHz RECTIFIER (Schematic T-5427)

An output voltage proportional to the current through one of the current sensing resistors associated with the preamplifier is fed into the differential pair Q701 and Q702 of the control oscillator. The second stage of amplification, Q703, drives the bridge rectifier consisting of CR707, CR708, CR709 and CR710 so that regardless of polarity a positive signal is applied to the collector of Q704. Temperature compensation of the diodes in the bridge is obtained from the diodes CR702, CR703, CR704 and CR705. The 150 KHz carrier output from the oscillator containing Q704 is proportional to the applied DC voltage. This output is transformer coupled to the rectifier circuit consisting of Q705, Q706 and Q707. The output of this circuit is a high impedance current generator whose current is rectified by CR711 and CR712.

H. AMMETER AND BASE SUPPLY (Schematic T-5428)

The output of the 150 Kc rectifier after filtering is amplified by Q801, Q802, and Q803. Differential input is provided for DC stability. The output of this amplifier drives the current meter on the front panel and provides an analog output. In addition to driving the ammeter the 150 KHz rectifier is coupled to the differential pair Q804 and Q805, the polarity input being determined by the PNP-NPN switch. Further amplification is obtained from Q806, Q807 and Q808. Since the differential pair of the base supply is referenced by the .ADJ. potentiometer, R809, a constant current would then be maintained in the transistor under test.

SECTION 4

CIRCUIT DESCRIPTION

I. CALIBRATING OSCILLATOR AND TRANSISTOR TEST JIG (Schematic T-5429)

The calibration oscillator operates at 4 KHz as an off-channel calibration source for the Model 2173-C. Stability of the oscillator is provided by CR709. The oscillator is a simple emitter coupled feedback oscillator. Bias is applied to the transistor under test from the base supply through the filters C904 and C905 as well as the base resistance selected.

J. CURRENT RANGE SELECTOR AND PREAMPLIFIER (Schematic T-5430)

The output of the transistor under test is applied through the interlock switch S-901B to the input of preamplifiers 1, 2, or 3 as selected by the current range switch. The output of each preamplifier is applied to the resistors of the current range switch. The variable capacitors associated with this switch are for high frequency compensation. The input differential transistor pair Q1001 and Q1002, are carefully selected for minimum noise. They are operated at optimum conditions for the 1, 3, and 10 micro-ampere ranges. Q1003, Q1004 and Q1005 provide further amplification to drive the resistor in the range switch. The preamplifier thus has a gain proportional to its resistance value, which, for varying G_m of the transistor under test, tends to give a constant output. Preamplifier #2 is the same as #1 except for changes in the operating currents of the transistors to provide an optimum noise match on the higher current ranges.

K. PREAMPLIFIER #3 and AMPLIFIER #1 (Schematic T-5431)

Preamplifier #3 is similar to Preamplifiers #1 and #2 with the exception of current changes for optimum noise match and additional dissipation capability provided by parallelling the output transistors. Amplifier #1 is a simple three-stage amplifier containing a push-pull output provided by Q1110 and Q1111.

L. COMPRESSOR, AMPLIFIER #2, NOTCH FILTER, COMPRESSOR AMPLIFIER and COMPRESSOR DRIVER (Schematic C-5432)

The input to pin E (#5) of the COMPRESSOR is the 4 KHz calibrate signal plus the transistor noise which is to be eventually metered. The COMPRESSOR and AMPLIFIER #2 serve to amplify both the calibrate signal and the noise signal. The calibrate signal is then passed through the 4 KHz NOTCH FILTER to the COMPRESSOR AMPLIFIER where it is transformed to DC whose magnitude is proportional to the 4 KHz input. The COMPRESSOR DRIVER is a straightforward DC amplifier which compares the DC output of the COMPRESSOR AMPLIFIER to a constant DC reference (CR1205). The error signal is amplified and applied to the COMPRESSOR where the voltage gain of that circuit is corrected to minimize the error between the DC output of the COMPRESSOR AMPLIFIER and the constant DC reference voltage across CR1205. The actual gain change in the COMPRESSOR is accomplished by changing the DC current through the compressor diodes. The voltage gain of the COMPRESSOR circuit is directly proportional to the impedance of these two diodes since they represent the collector loads of Q1201 and Q1205. The relationship between the impedance of the compressor diodes and the DC current through them is very nearly a linear, inverse one.

The closed loop then represented on C-5432 serves to automatically adjust the voltage gain of the COMPRESSOR to cancel out the variation in gain in the transistor under test.

If for any reason the loop cannot be corrected and an unbalance exists across the bases of Q1212 and Q1215 (such as when there is no transistor in the test socket) Q1201 will be switched on to activate relay K1211 which grounds the noise output of the Control Unit. This provision prevents an erroneous noise reading from being taken.

SECTION 5

MAINTENANCE AND CALIBRATION

A. GENERAL

1. The Model 2173-C Control Unit uses semiconductor components throughout with the exception of the AGC relay. Preventive maintenance is not, therefore, required.
2. It is recommended that the top of the case be removed only after the normal operation checks given below have been performed and the results indicate the necessity of doing so. Servicemen are cautioned not to change calibration adjustments unless it is firmly established that adjustment is required.
3. Main power should be turned off when connecting or disconnecting the printed circuit assemblies to avoid damaging semiconductor components through the transient voltages thus created. Care should be taken to insure proper alignment of the printed circuit assemblies when replacing them in their sockets.
4. If servicing is required, it is advisable to consult the warranty page for inwarranty servicing information.

B. NORMAL OPERATION

1. Get Bias Voltage

With no device in the test sockets, the shield cover closed and BIAS SELECTOR switch in the GATE BIAS VOLTAGE position the ranges of the voltmeter, the meter itself and the 0 to 15 volt range of the ADJ control can be checked.

2. Ammeter.

The fastest and easiest method of checking for normal operation of the ammeter is to check with a transistor in the socket and the BIAS SELECTOR switch in the COLLECTOR DRAIN CURRENT position. Two things can be checked in this manner. With the ammeter reading a particular amount, there should be little change in scale reading when the range switch is changed through all the positions. With the current control fully clockwise, the ammeter should read off scale. If the ammeter functions in the way described, operation is normal. For calibration of the ammeter, refer to Paragraph E-3 of this section.

3. Voltmeter.

The voltmeter and the collector voltage supply can be readily checked with or without a transistor in the test socket. With the collector/drain

voltage switch in the 100 position, the voltmeter should read approximately zero with the ADJ. knob fully counterclockwise and should read slightly more than 60V with the ADJ. knob fully clockwise. Calibration of the voltmeter is described in Paragraph E-1 of this section.

4. AGC Relay

The AGC relay short circuits the output terminal of the Control Unit when a noise measurement should not be made. This will occur when the jig shield cover is open, a transistor is not in the socket, the transistor in the socket is in some way faulty or if the bias condition on the transistor is not sufficient for normal transistor operation. In normal operation, the AGC relay will probably be heard as it operates after a transistor has been put in the jig and the current has stabilized.

C. REMOVAL OF THE COVERS

Either the top or the bottom of the Control Unit may be removed for access to the inside of the equipment. No other screws on the sides or front should be loosened or removed.

D. CHANGING THE INPUT VOLTAGE

This instrument has been designed to operate from a 117V or 234 VAC power source. The plate on the rear of the instrument near the power cord indicates the voltage and frequency at which it should be operated. If the input voltage must be changed the following procedure should be observed.

NOTE: When the input voltage on the Model 2173C is changed the voltage at the rear outlet is also changed requiring the voltage change in the companion Filter Unit.

- a. Remove the end bell on the power switch side of the instrument (Two screws in front panel, three screws in top, three screws in bottom and two screws in rear panel).
- b. Change the transformer primary connections by moving the jumpers indicated on the primary connection sketch; Figure 5-1

*7. noise Cal. 50mv in from 200K, .5v out (KHz) from 200K
Transistor in 500K -*

SECTION 5

MAINTENANCE AND CALIBRATION

- c. Reverse the plate on the rear of the instrument to indicate the new power source, replace the end bell, and double check the companion Filter Unit to see if it is wired for the new voltage.

E. DETAILED CALIBRATION

1. Voltmeter

The calibration of the voltmeter is obtained from 1% resistors installed at the factory and no further calibration should be required.

2. 18 Volt Bias Supplies

All of the 18 volt bias supplies in the Control Unit are adjusted to 18 volts (± 0.5 volts) using the same method. As an example, the plus 18 volt supply (Schematic T-5422) is adjusted through the selection of R206. The other three 18 volt supplies are adjusted with resistors corresponding to R206.

3. Ammeter

Although the ammeter circuitry is somewhat complicated since it involves a controlled feedback to the transistor under test, the only adjustment that would normally be required would be that of R722. This can readily be done by connecting an external ammeter in series with the collector lead and making the adjustment so that the 2173-C panel meter agrees with the external meter. Any reasonable current range may be used for this.

4. Calibrate Oscillator

C903 is adjusted to set the oscillator frequency to 4KHz. The output level of the calibrate oscillator is then set to 100 microvolts as measured at the test socket from the emitter lead to ground. A transistor need not be in the socket to make this adjustment.

5. Preamplifier High Frequency Compensation

The capacitors C1002 through C1007 are compensating capacitors for 100 KHz response. These may be adjusted by checking the response of the 2173-C either with a noise generator or a sine wave oscillator so that each range is flat from 1 KHz to 100 KHz.

6. Notch Filter Alignment

To align the two notch filters shown on Schematic C-5432 an oscilloscope should be used to detect magnitude of the 4KHz signal appearing on C1216. Adjust C1215 for a minimum of 4KHz. Moving the oscilloscope to the output terminal, adjust C1218 again for a minimum of 4KHz. To perform this a transistor must be in the socket and the shield cover closed.

7. Noise Calibration

The overall gain of the Control Unit is adjusted to 10,000 using R1238 in the compressor amplifier. The procedure is to apply a 100 Hz signal to the white pin jack on the test jig panel and adjust the apparent gain from this point to the output jack to ten. The input attenuator made up of R910 and R911 provides the additional 1000 to 1 required for the proper gain adjustment. The input impedance at the pin jack is 600 ohms, thus matching a QTL Model 420 Noise Generator for calibration purposes.

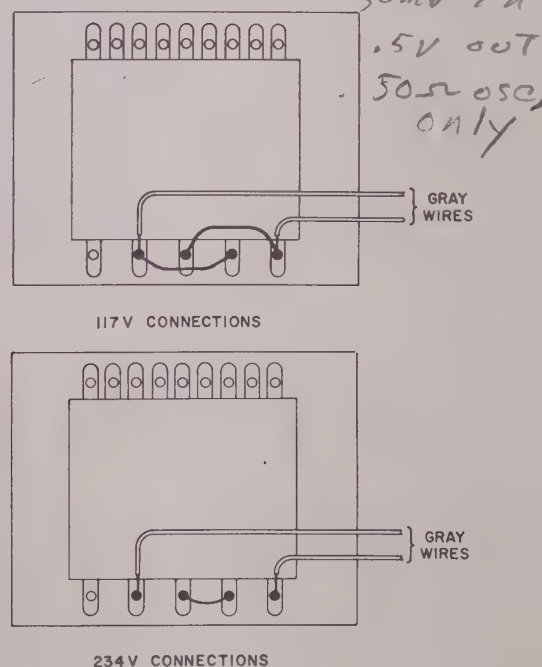


FIGURE 5-1
INPUT VOLTAGE CONNECTIONS

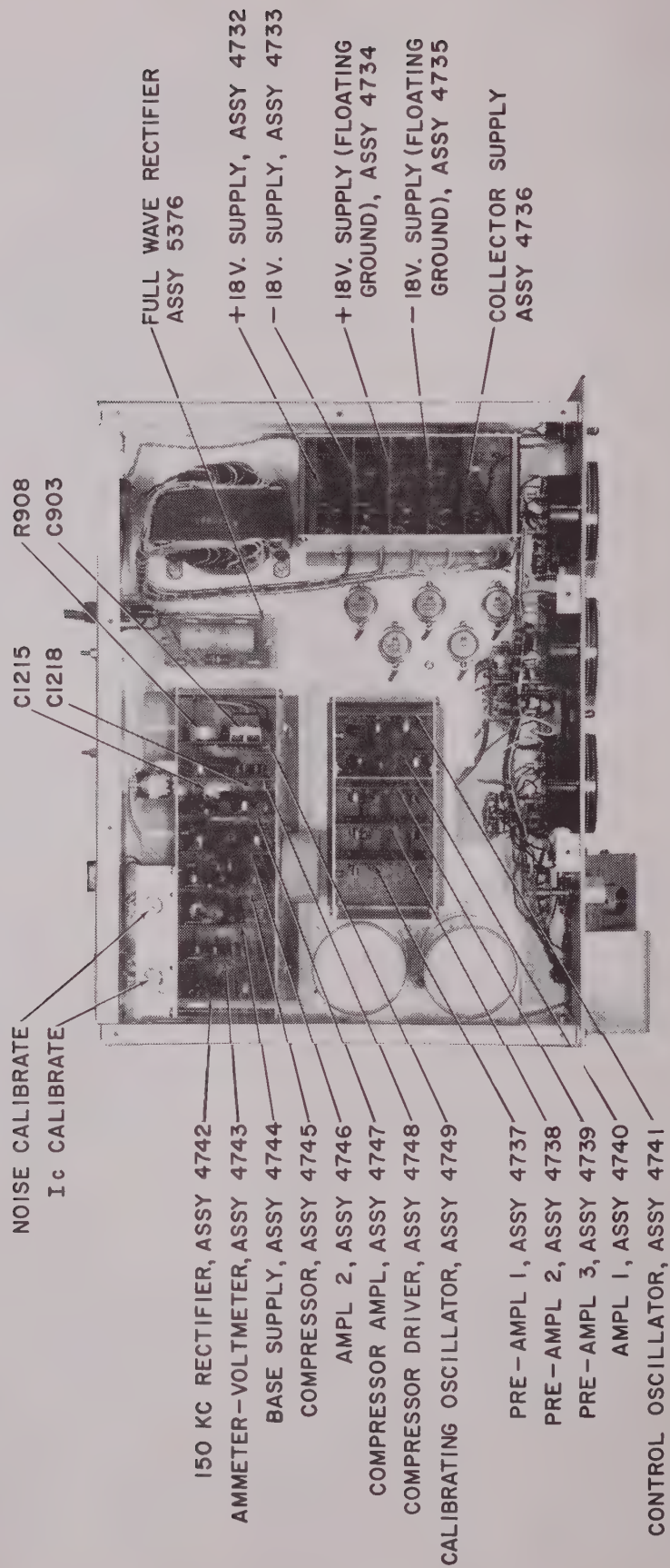


FIGURE 5-2
LOCATION OF PRINTED CIRCUIT
BOARD ASSEMBLIES

SECTION 5

MAINTENANCE AND CALIBRATION

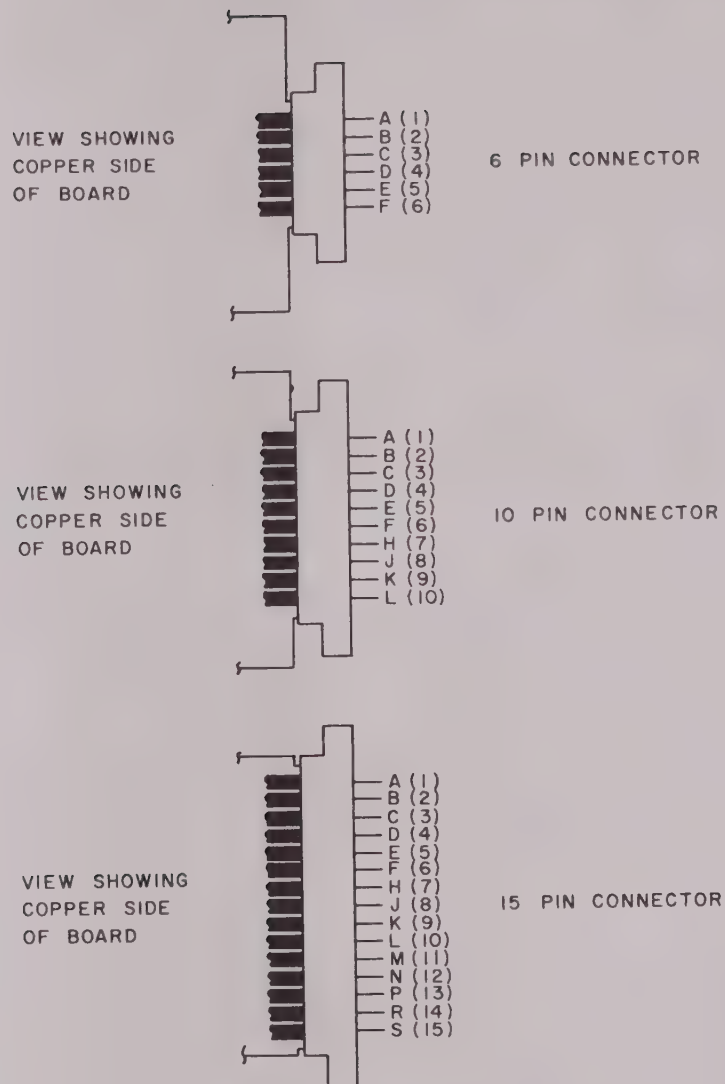


FIGURE 5-3

PRINTED CIRCUIT BOARD CONNECTOR LUG IDENTIFICATION

SCHEMATIC LEGEND

k = 1000

Unless Otherwise Specified:

 = Screw Driver Adjustment

All Resistances in Ohms

 = Front Panel Control

All Resistors 1/2 Watt

* = Factory Select

All Capacitances in Microfarads

SEMICONDUCTOR LEGEND

Changes and improvements in the semiconductor products available for commercial use necessitate type changes from time to time. To eliminate confusion and costly paperwork, many of these changes will be covered in the following legend. The purpose of this legend is to acknowledge the fact that the type number on a semiconductor found in a piece of equipment will not necessarily correspond with the type number given on the schematic diagram.

The legend is not intended to be an interchangeability list although in many cases good quality

components* within a given category may be substituted with acceptable results. Normally, replacements should be made using components having the same type number as the component being replaced.

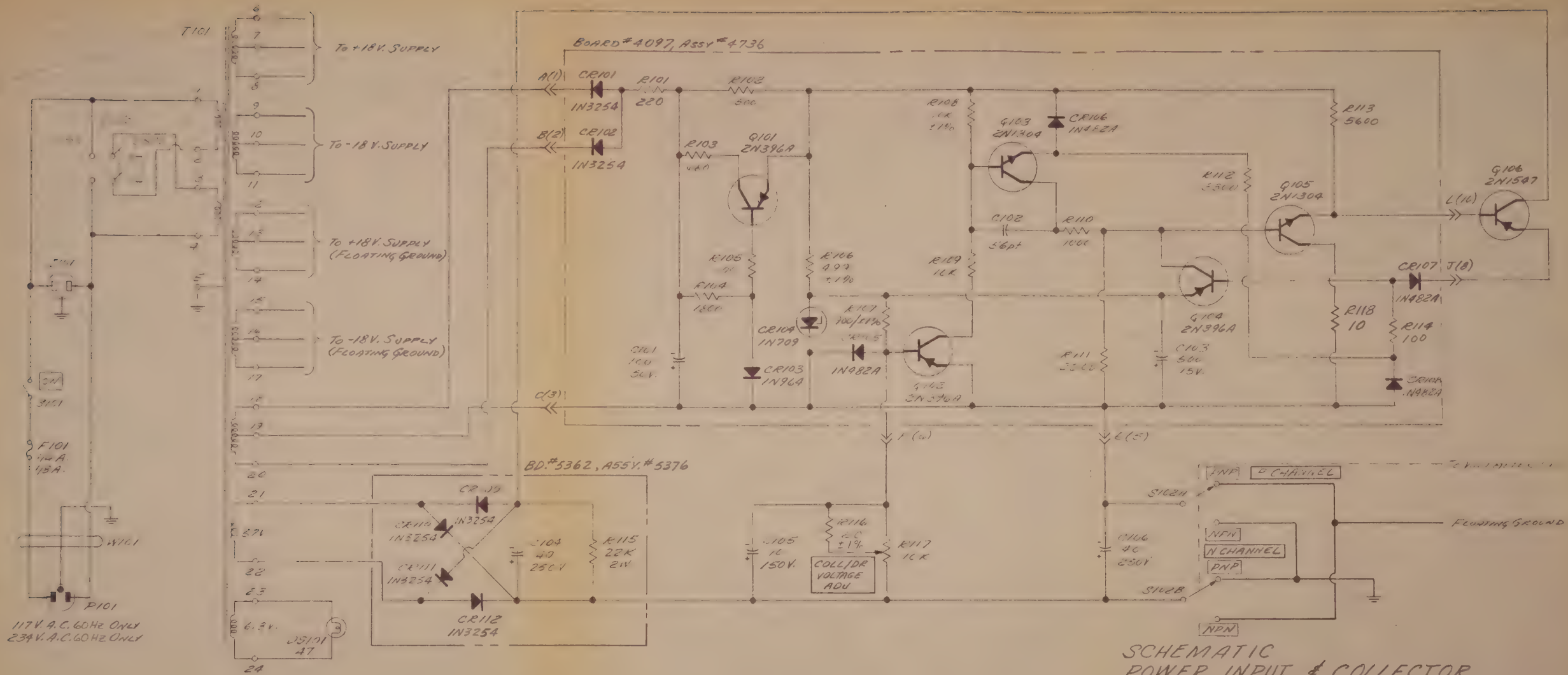
Those components bearing an asterisk on the schematic diagram are factory selected components and should be obtained from Quan-Tech Laboratories.

*It should be noted that the incoming inspection procedure followed at Quan-Tech Laboratories includes noise screening on most semiconductors.

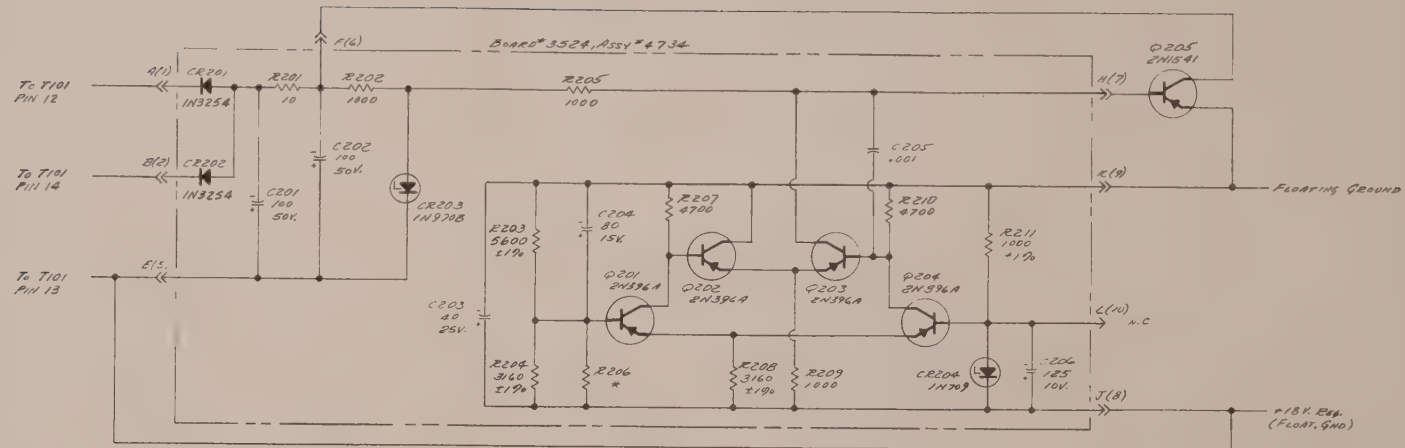
TYPE # ON SCHEMATIC	TYPE # IN EQUIPMENT
---------------------	---------------------

TI480	2N1613
TI494	2N1613
1N703	1N748
1N709	1N753
1N2859	1N3253, 1N3254
1N2862	1N3254

2N396A	4JX1G759, 4JX1D653
2N414	2N396A, 4JX1G759, 4JX1D653
2N929	220N2, A642, 2N3566
2N1515	2N3644
2N1613	2N3566
2N2219	220N2, A642, 2N3566
2N2603	2N3250
2N3250	2N3644

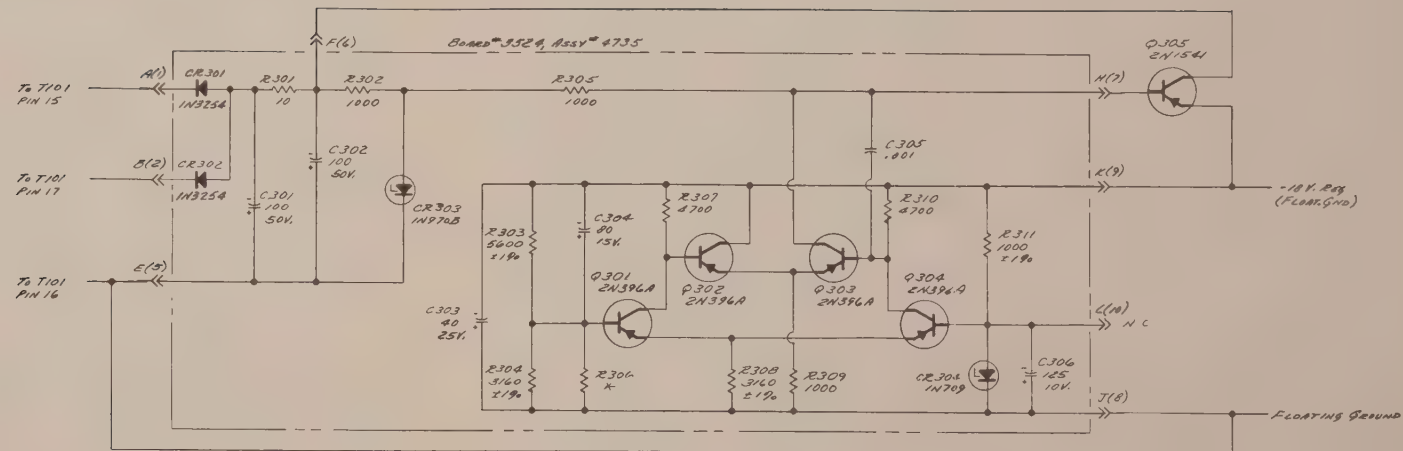


SCHEMATIC
POWER INPUT & COLLECTOR
VOLTAGE SUPPLY
MODEL 2173C



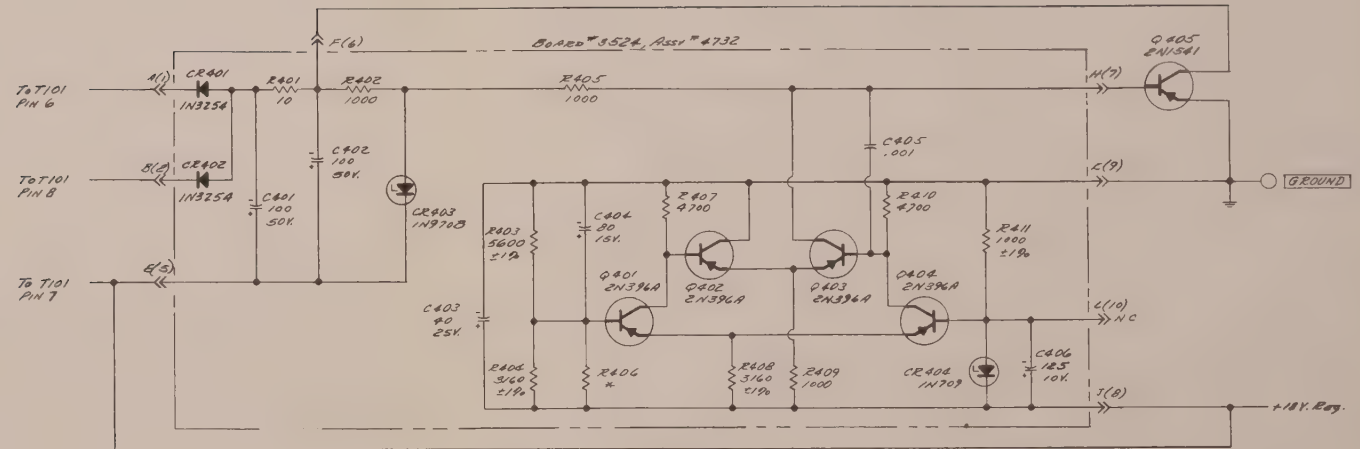
SCHEMATIC
+18 VOLT SUPPLY (FLOATING GROUND)
MODEL 2173C

T-5422-A



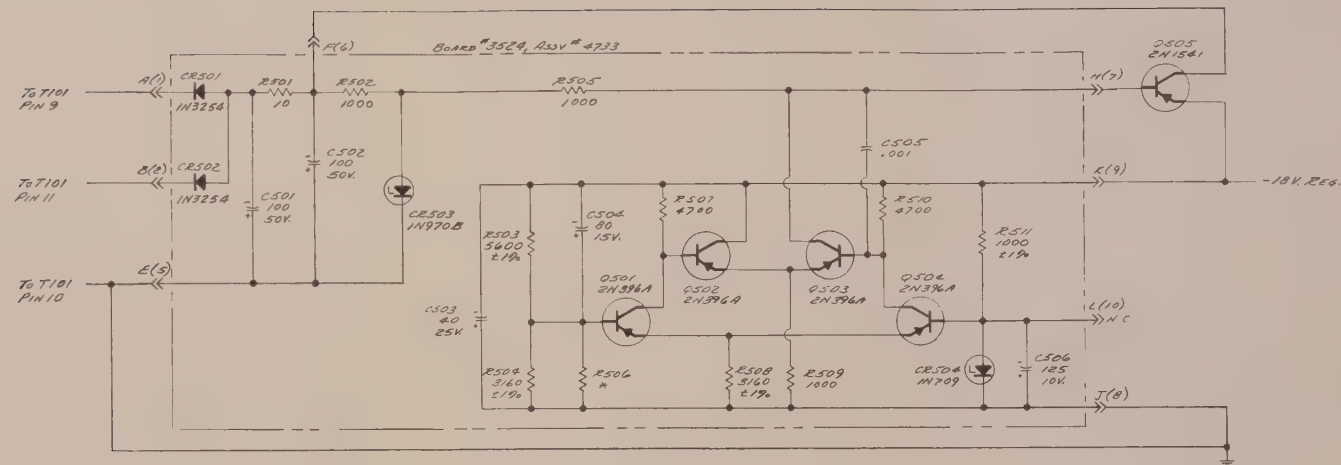
SCHEMATIC
-18 VOLT SUPPLY (FLOATING GROUND)
MODEL 2173C

T-5423-A



SCHEMATIC
+18 VOLT SUPPLY
MODEL 2173C

T-5424-A



SCHEMATIC
-18 VOLT SUPPLY
MODEL 2173C

T-5425-A

PRELIMINARY ELECTRICAL TEST PROCEDURE

MODEL 2173-C

S/N 200 to

- I MISCELLANEOUS
- II 18 VOLT POWER SUPPLIES
- III COLLECTOR SUPPLY
- IV VOLTMETER CALIBRATION
- V COLLECTOR CURRENT CALIBRATION
- VI GATE BIAS
- VII CONTROL OSCILLATOR
- VIII CALIBRATE OSCILLATOR
- IX NOTCH FILTER
- X CALIBRATE ATTENUATOR
- XI SYSTEM GAIN
- XII COMPRESSOR
- XIII FREQUENCY RESPONSE
- XIV SYSTEM NOISE

EQUIPMENT REQUIRED

- I VTVM HP 400D OR EQUIVALENT
- II AUDIO OSCILLATOR HP 200CD OR EQUIVALENT
- III VOM AVOMETER MODEL 8 OR EQUIVALENT
- IV OSCILLOSCOPE TEKTRONIX TYPE 503 or 515A
- V FREQUENCY COUNTER
- VI FILTER QTL MODEL 2181
- VII AMPLIFIER QTL MODEL 203
- VIII WAVE ANALYZER QTL MODEL 303
- IX NOISE GENERATOR QTL MODEL 420

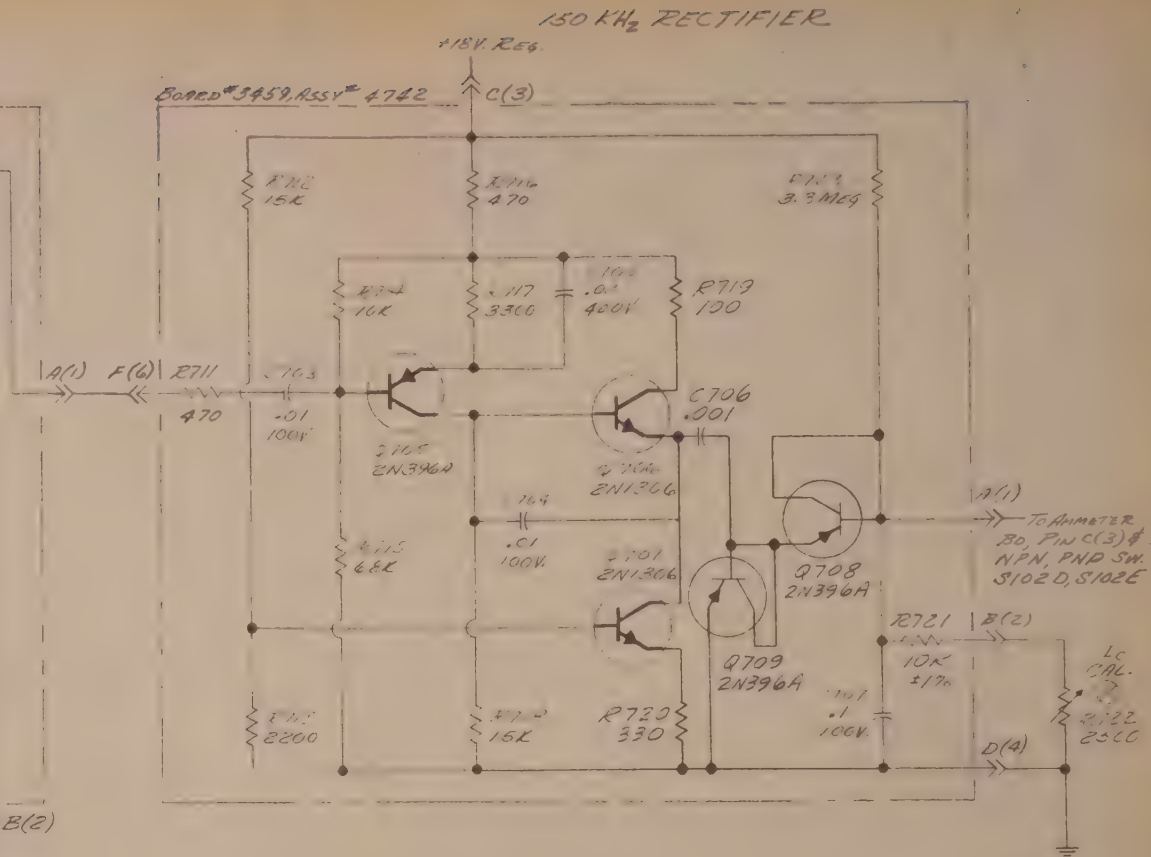
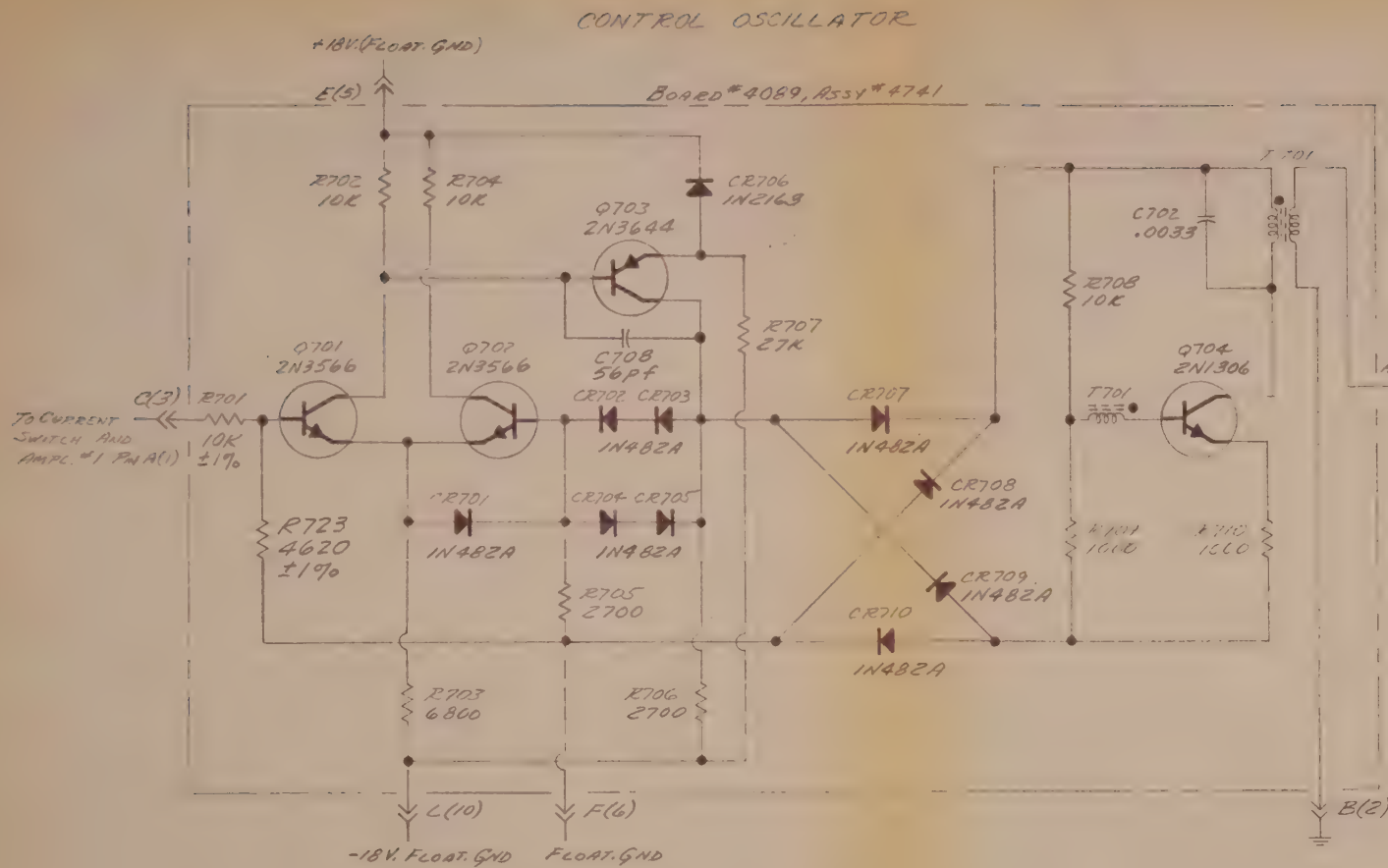
A-2133 A

PAGE 1 of 7

5-19

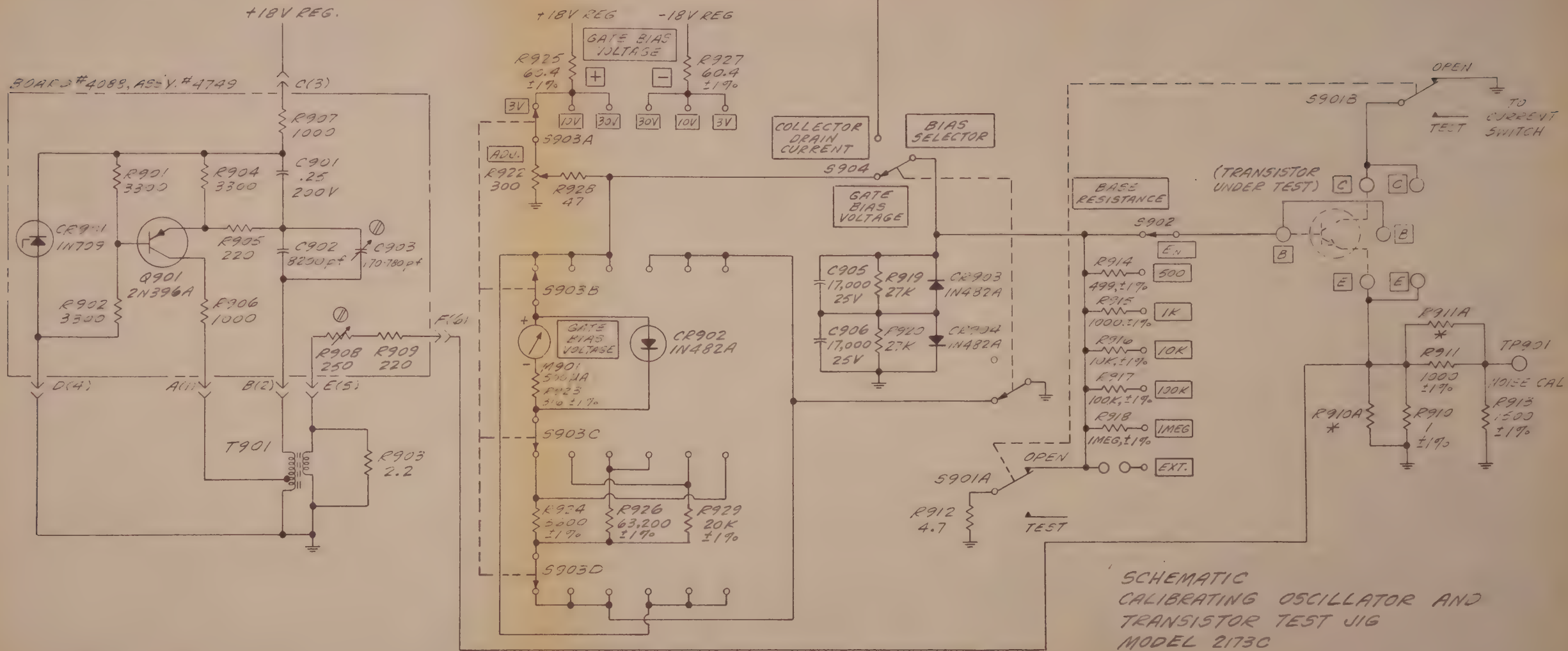
VOLTMETER CIRCUIT

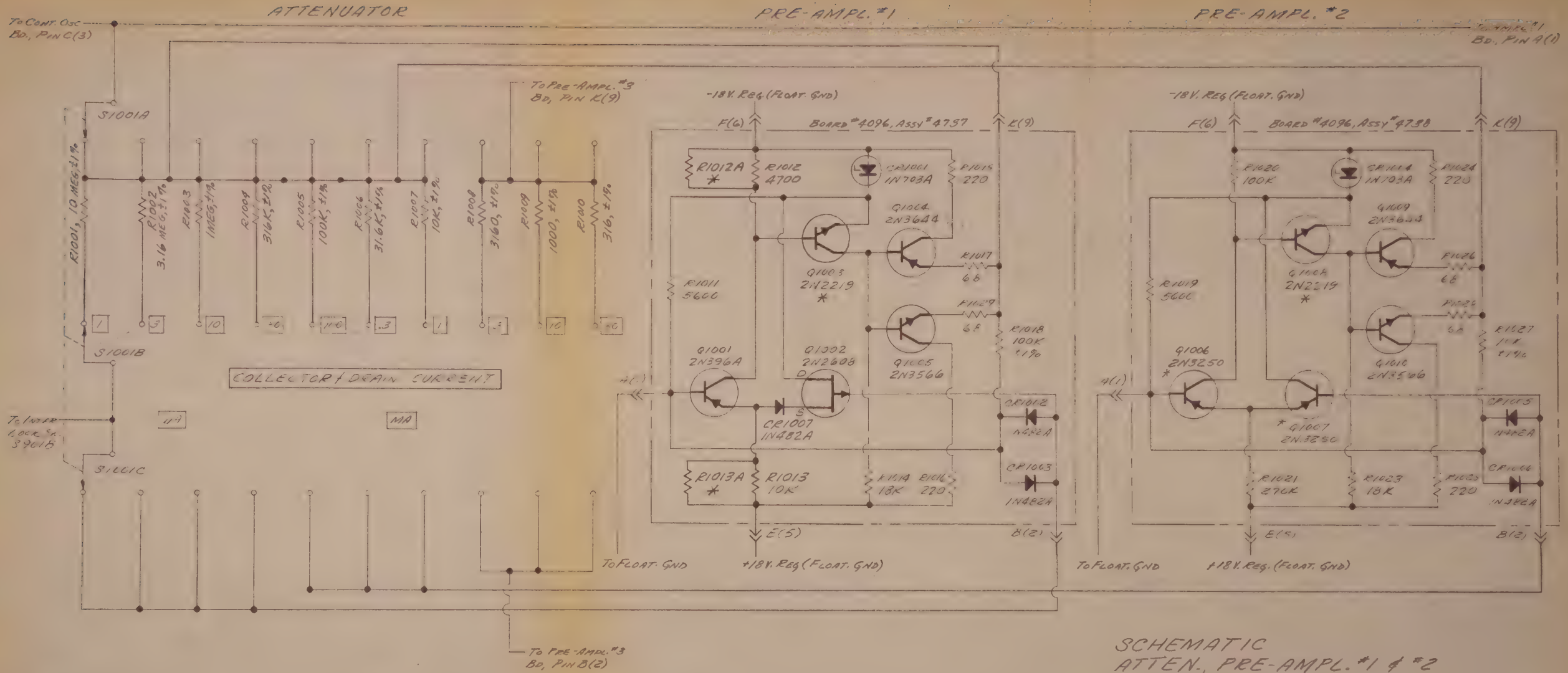
SCHEMATIC
VOLTMETER CIRCUIT
MODEL 2173C

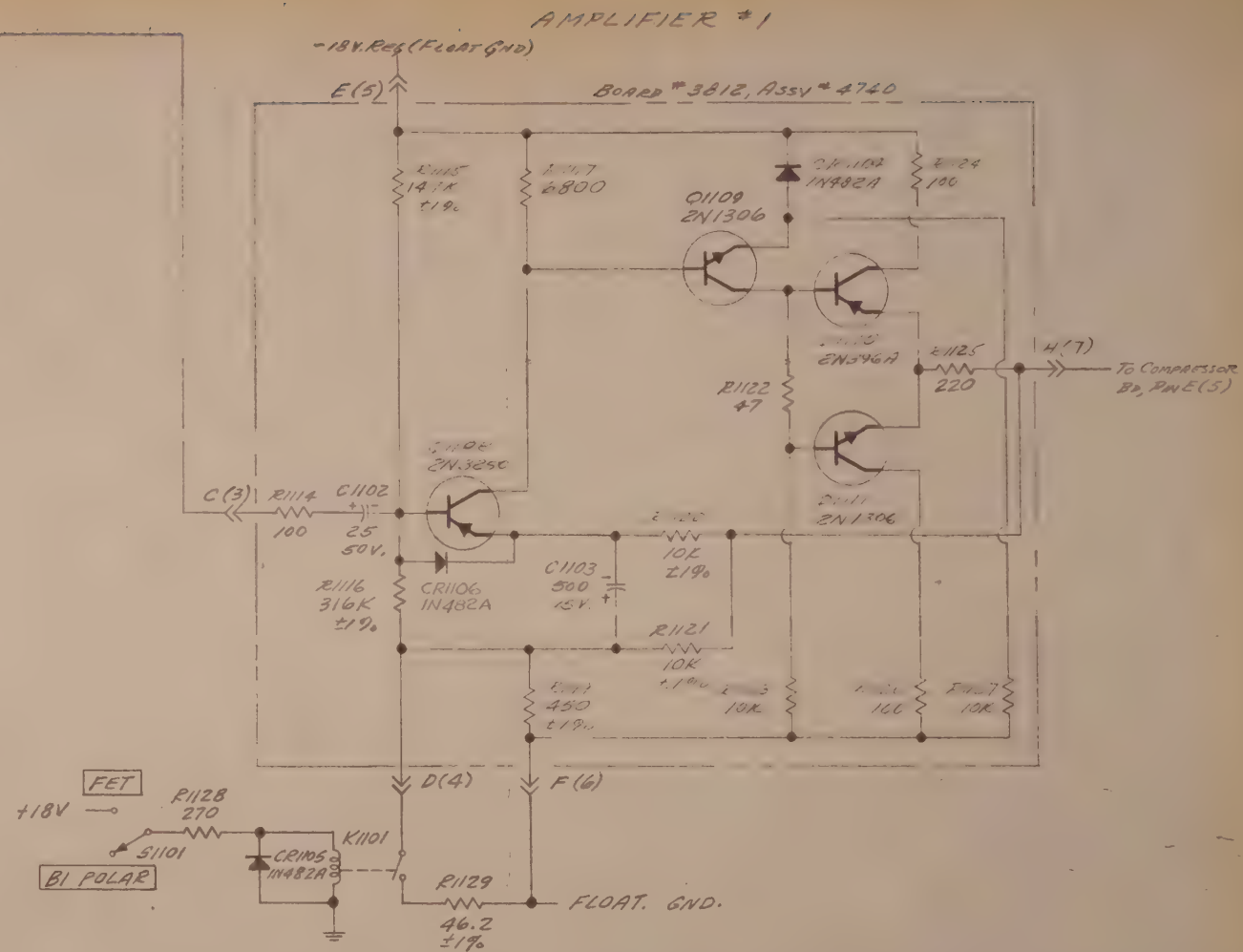
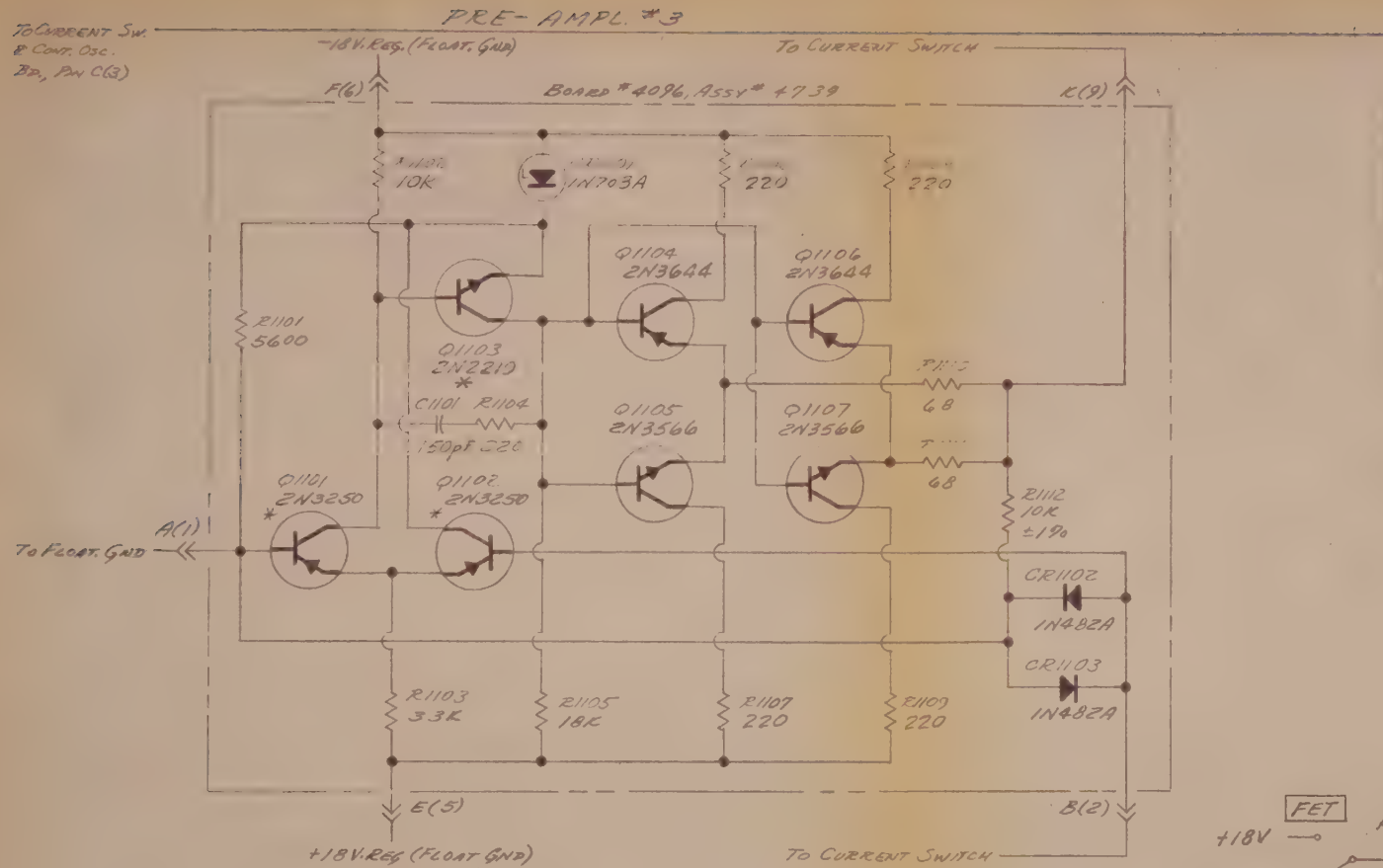


SCHMATIC
CONTROL OSC. & 150 KHz RECT.
MODEL 2173C

TO BASE
SUPPLY BD.,
PIN D(4)

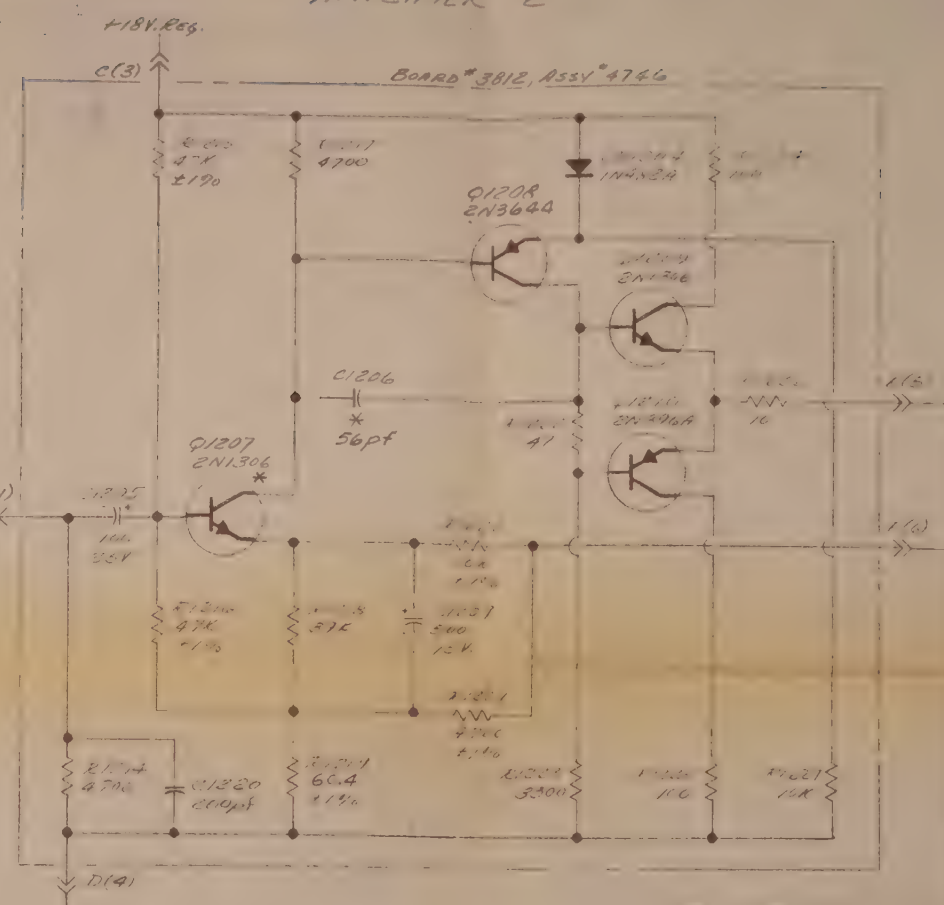
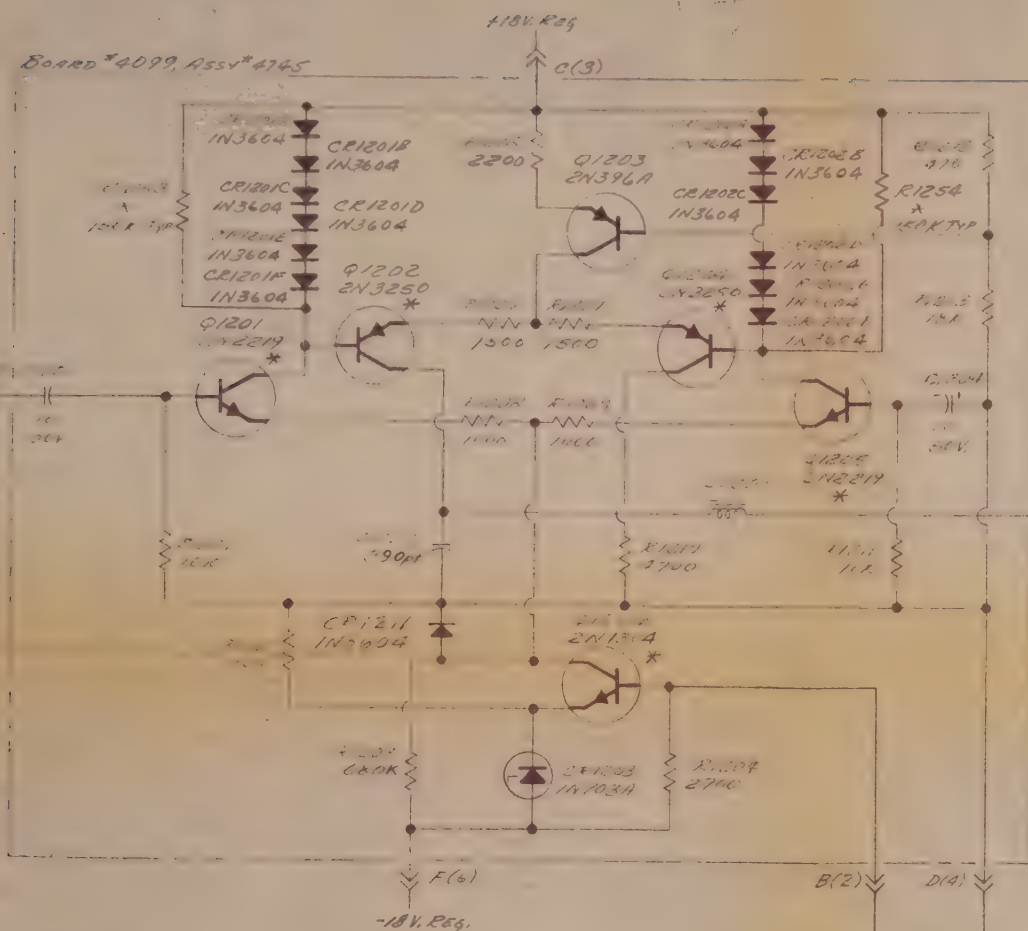




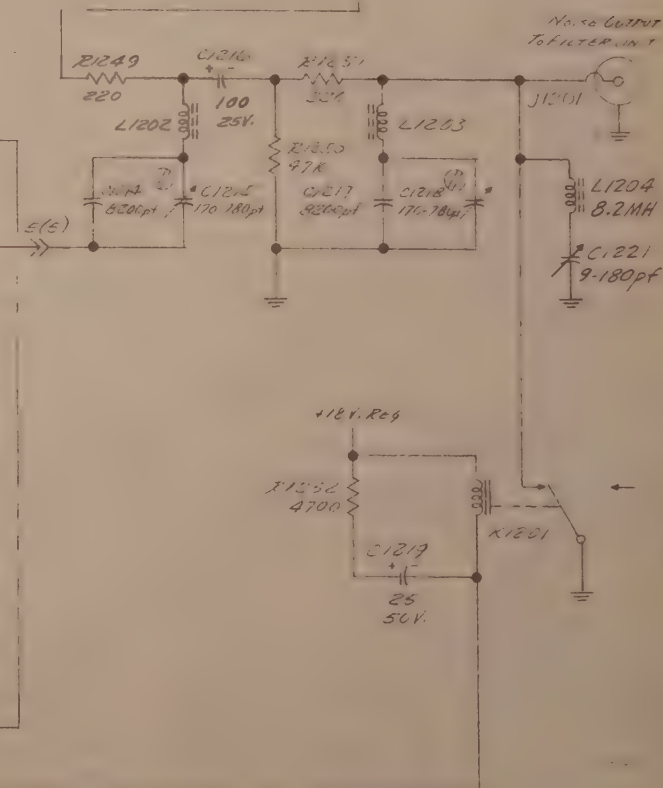
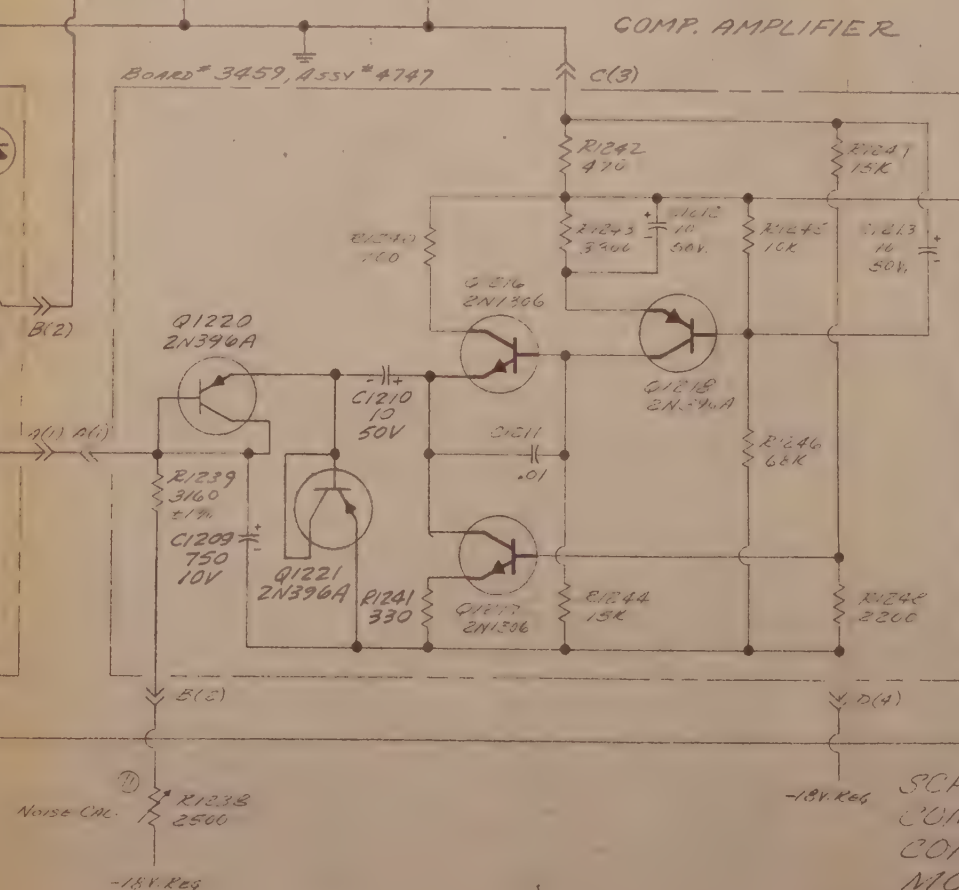
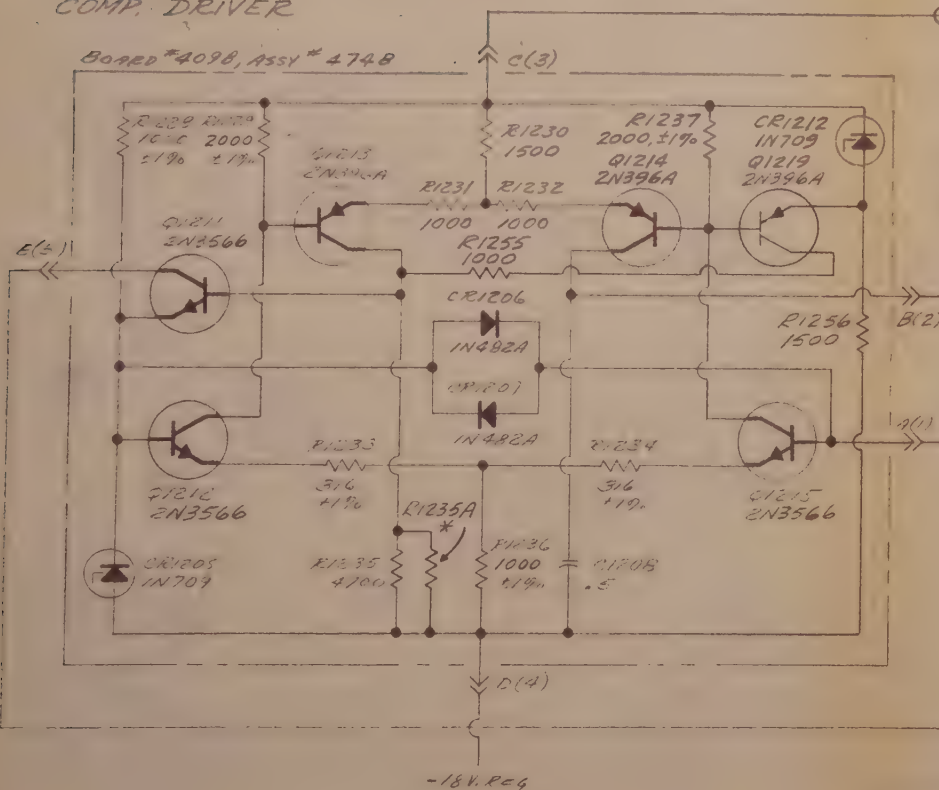


SCHEMATIC
PRE-AMPL. #3 & AMPL. #1
MODEL 2173C

AMPLIFIER #2



COMP. DRIVER



SCHEMATIC
COMPRESSOR, AMPL #2, NOTCH FILTER,
COMP. AMPL. & COMP. DRIVER
MODEL 2173C

I. MISCELLANEOUS

- A. Check general condition of unit for dirt, engraving defects, scratches, burred screws, knob alignment etc.
- B. Check mechanical zero of meters
- C. Check continuity of line ground to chassis and isolation of line to chassis.

II. 18 VOLT POWER SUPPLIES

- a. +18 volt Ass'y 4732
 - b. -18 volt Ass'y 4733
 - c. +18 volt (floating) Ass'y 4734
 - d. -18 volt (floating) Ass'y 4735
1. Select; R-206 Ass'y 4732, R306 Ass'y 4733, R406 Ass'y 4734, R506 Ass'y 4735 for $18v \pm .5v$.
 2. Measure output of each supply for noise and ripple; should be less than 10 μv RMS.

III. COLLECTOR SUPPLY (Ass'y 4736)

- a. Set FULL SCALE VOLTS to 100.
- b. Turn V.ADJ. full c.w.
- c. Close interlock and measure voltage from collector to ground. Limit 60v.
- d. Turn V.ADJ counterclockwise; voltage should drop smoothly and reach a minimum of $> .2v$.
- e. Measure noise and ripple at MAXIMUM voltage limit:
 $< 100 \mu v$ RMS.

IV. VOLTMETER CALIBRATION (Ass'y 4743)

- A. In MPN position set V.ADJ. to exactly 10v from collector to ground. FULL SCALE set to 10v.
- B. Measure V analog. Limit: $10v \pm 5\%$
- C. 2173 voltmeter should indicate $10v \pm 2\%$; if not, shunt R616. (Typ.470K)
- D. Switch to PNP; 2173 voltmeter should indicate $10v \pm 2\%$; if not, shunt R609. (Typ.470K)
- E. Check all ranges for F.S. accuracy and linearity. Limit $\pm 2\%$ F.S.

V. COLLECTOR CURRENT CALIBRATION (Ass'y 4743)

A. D.C. offset, pre-amp No. 1 Ass'y 4737

1. Set collector range switch to 30 μ a.
2. No transistor in socket
3. Connect D.C.Voltmeter from pin No. 1 to pin No. 9 of Ass'y 4737.
4. Shunt R-1012 or R-1013 for $0\text{ v} \pm 25\text{ mv.}$

B. CURRENT METER CALIBRATION

1. Insert NPN transistor in test socket
2. Set V. ADJ to 10v on 10v range
3. Close interlock
4. Set collector current switch to 1 MA range
5. Set collector CURRENT ADJ. for 1 MA indication on CURRENT meter.
6. Insert external current meter in series with test transistor collector. Close interlock.
7. Adjust I_C CAL.(R722) for 1 MA indication on external meter.
8. Measure I analog; should be $10\text{v} \pm 5\%$
9. Check current meter accuracy using a PNP transistor. Limit: $\pm 5\%$. Split error between NPN and PNP if necessary.
10. Check current meter accuracy on all ranges. Limit: $\pm 5\%$ of F.S.
11. Lock I_C CAL Pot.

VI. GATE BIAS

A. Switch BIAS selector to GATE BIAS.

- B. Measure voltage from base of test socket to ground for all ranges. Limit: $\pm 5\%$ F.S. Maximum voltage should be $15\text{v} \pm 5\%$.

VII. CONTROL OSCILLATOR (Ass'y 4741)

- A. With a transistor in test socket operating at E_c 10v at I_c 1 MA, measure frequency and amplitude at pin 1 of Ass'y 4741. Frequency approx. 150-170 KHz. Amplitude approx. .5 to .6v RMS.

VIII. CALIBRATE OSCILLATOR (Ass'y 4749)

- A. Insert transistor in test socket at E_c 10v, I_c 1 MA $E_g = E_p$. Close interlock. AGC Relay^c should click indicating AGC loop is operating correctly.
- B. Connect VTVM to TP1 (collector of Q1208 Ass'y 4745) and counter to output of VTVM).
- C. Adjust C-903 (Ass'y 4749) to 4000 cycles.
- D. VTVM should read approx. 1.2v RMS.
- E. Connect wave analyzer to emitter of test socket, close interlock. Check wave analyzer accuracy at 4000 cycles.
- F. Peak wave analyzer at 4000 cycles and adjust R908 Ass'y 4749) for 100 μ v.

IX. NOTCH FILTER

- A. Insert transistor in test socket at E_c 10v I_c 1 MA, $R_g E_n$. Close interlock.
- B. Connect VTVM to TP1
- C. Adjust C-1215 for minimum 4 KHz indication.
- D. Connect VTVM to NOISE OUTPUT (J1201).
- E. Adjust C-1218 for minimum 4 KHz indication
 - 1. Re-adjust C1215 for minimum VTVM indication
- F. Adjust C-1221 (150 KHz trap) for minimum indication on VTVM.

X. NOISE CALIBRATE ATTENUATOR

- A. Connect a 10v 1 KHz signal to test jack on test jig. Ground to braid.
- B. Connect VTVM from emitter of test jig and ground to braid.
- C. VTVM should read 10 mv $\pm$ 1% .

XI SYSTEM GAIN

- A. Connect noise output (J-1201) of Model 2173-C to input of Model 2181 (a 4620 ohm resistor may be used instead of Model 2181).
- B. Connect a 100 mv 1 KHz signal to test jack.
- C. Connect VTVM to noise output.
 - 1. Output must be terminated with a 4620 ohm resistor or the Model 2181.
 - 2. Adjust R-1238 for 1 volt indication on VTVM.
 - a. A Model 2181 must be on the 3000 range.

XII COMPRESSOR

- A. AGC Loop Gain
 - 1. Set current to 100 μ a range.
 - 2. V ADJ. to zero.
 - 3. Feed a 4 KHz signal thru a 1 meg. resistor to collector of test jig. Close interlock.
 - 4. Observe waveshape at TPI.
 - 5. Tune oscillator for minimum 4 KHz indication.
 - 6. Increase oscillator level until 4 KHz signal changes level.
 - 7. Measure 4 KHz level at pin 5 of Ass'y 4745. Should be .6 to .7 v RMS; if not, shunt R-1221 or R1210.
- B. Balance
 - 1. Set current to 1 MA range
 - 2. Same as XII, A, 2,3,4,5
 - 3. Decrease 4 KHz level, waveshape should remain a sine wave.
 - a. Pad R-1253 or R-1254 to maintain a sine wave.
 - 4. Increase 4 KHz level until level remains constant; Approx. 3 mv input
 - a. AGC relay should click; if not, pad R-1235 Ass'y 4748) Typ. 33K

C. Range

1. Same as XII, F, 1,2
2. Measure oscillator voltage when relay clicks at low end (approx. 8 mv.)
3. Increase oscillator level until level at TP1 changes level. (approx. 5v).
4. Compressor range should be $> 600:1$
 - a. $\text{ex. } \frac{\text{high level}}{\text{low level}} = \frac{5\text{v}}{8\text{mv}} = 625$
5. Continue to increase level; relay should click at same voltage as XII C 4 (5v) or no greater than 20%.

D. PL-Polar FET

1. Same as XII 1,2 except measure voltage at pin 5 of Ass'y 4745.
2. Set level for .5v and switch to FET.
3. Voltage should be $5\text{v} \pm 10\%$.

E. Level

1. Insert a silicon transistor in test socket set to E_c 10v, I_c 100 μa on 100 μa range. Close interlock.
2. Measure 4 KHz level at pin 5 of Ass'y 4745.
3. Level should be .5v RMS $\pm 10\%$.

XIII FREQUENCY RESPONSE

- A. Connect output of 2173 to input of 2181.
- B. Insert known good silicon transistor in test socket set to E_c 10v, I_c 10ma, R_g-E_n . Close interlock.
- C. Connect QTL Model 420 to test jack on jig. Set to UNTERM, 500 $\mu\text{v}/\sqrt{\sim}$.
- D. Set Model 2181 to 1000
- E. Check accuracy of all channels $\pm 2\%$ F.S.
- F. Check accuracy of 100 Kc channel for all current ranges. Limit $\pm 2\%$ F.S. except 10 μa range and lower no limit but must roll off at 100 Kc.
 1. If necessary C-1203 (Ass'y 4745) may be padded to make frequency flat at 100 Kc.

XIV SYSTEM NOISE

- A. Feed a 4 KHz signal thru a resistor (see chart) to the collector of test socket.
- B. Connect 2181 to output of 2173.
- C. Connect VTVM to NOISE output of 2173.
 1. Tune oscillator for minimum reading.
 2. See chart for 4 KHz level, resistor and limits.
- D. Check a known good transistor.
 1. E_n should read $1.5 \text{ nv}/\sqrt{\sim}$ @ 10 Hz or less.
 2. Check low current shot noise reading.
 - a. $I_c = 1 \mu\text{a}$ should read $14 \text{ nv}/\sqrt{\sim}$
 - b. $I_c = 3 \mu\text{a}$ should read $8.2 \text{ nv}/\sqrt{\sim}$
 - c. $I_c = 10 \mu\text{a}$ should read $4.5 \text{ nv}/\sqrt{\sim}$
 3. Check with $I_c = 10 \mu\text{a}$ $R_g = 10\text{K}$, should read $12.6 \text{ nv}/\sqrt{\sim}$

10 Hz SYSTEM NOISE

CURRENT RANGE	RESISTOR	4KHz VOLTAGE	BI-POLAR 10 Hz MAX.	4 KHz VOLTAGE	FET 10 Hz MAX.
1 ua	10 meg.	40 mv.	3.0	4 mv.	30
3 ua	10 meg.	126 mv.	2.0	12.6 mv.	20
10 ua	10 meg.	400 mv.	1.5	40 mv.	10
30 ua	10 meg.	1.26 v.	.75	126 mv.	7.5
100 ua	1 meg.	400 mv.	.7	40 mv.	4
.3 ma	1 meg.	1.26 v.	.65	126 mv.	4
1 ma	1 meg.	4 v.	.6	400 mv.	3
3 ma	1 meg.	12.6 v.	.6	1.26 v.	3
10 ma	100 K	4 v.	.6	400 mv.	3
30 ma	100 K	12.6 v	.6	1.26 v.	3

